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Summary:

Large differences between observations taken at 0 and 12~GMT have been revealed during routine monitoring of observations at the Data Assimilation Office (DAO) at NASA's Goddard Space Flight Center (GSFC). As a result, an investigation has been conducted to confirm the large differences and isolate its source. The data clearly shows that 0/12~GMT differences are largely artificial especially over the central US and that the differences largely originate in the post processing software at the observing stations. In particular, the release time of the rawinsonde balloon may be misspecified to be the synoptic time which would lead to the miscalculation of the bias correction that accounts for solar radiation effects on the thermistor.

Large 0/12 GMT Differences of US Vaisala RS80 Observations

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1. Introduction

The National Weather Services (NWS) in the United States (US) launches rawinsondes to measure meteorological quantities including temperatures and heights. These rawinsondes are released twice daily, nearly one hour before 0 and 12 GMT, and typically reach pressure levels of 10 hPa or higher. The observations are widely used in performing analysis and initializing forecast models.

Recently, large differences between observations taken at 0 and 12 GMT have been revealed during routine monitoring of observations at the Data Assimilation Office (DAO) at NASA's Goddard Space Flight Center (GSFC). As a result, an investigation has been conducted to confirm the large differences and isolate its source. This paper discusses the methods used in the investigation and presents the findings.

2. Method

The observed values used in this study were provided by the National Center for Environment Prediction (NCEP). A random sample of the observed values were compared with values from the National Climatic Data Center (NCDC) which acquires its data directly from the stations via floppy disk. The temperature differences were as large as 0.2 °C and height differences as large as 5 m. These differences can be attributed to the imprecision of the Global Telecommunication System (GTS), a meteorological network through which NCEP receives its data. Rawinsonde observations on the GTS are reported using the WMO rawinsonde code (Office of the Federal Coordinator for Meteorology, 1997). With the WMO code, temperature data is encoded to an accuracy of 0.2 °C, and height data above 500 hPa is reported to the nearest dekameter.

The 0/12 GMT differences were calculated by using the following expression:

$$\delta = \begin{cases} O_{00} - 0.5(O_{-12} + O_{+12}) \\ O_{00} - O_{-12} \quad \text{if } O_{12} \text{ is missing} \\ O_{00} - O_{12} \quad \text{if } O_{-12} \text{ is missing} \end{cases} \tag{1}$$

where δ is the 0/12 GMT difference, O_{00} is the observation at 0 GMT and O_{-12} and O_{12} are the observations at 12 hours before and after 0 GMT. These observations were subject to the complex quality control developed by NCEP (Collins, 2001a and Collins, 2001b). Equations 1 was formulated to remove most if not all of the effects of long term interseasonal trends during such months as March and September.

The monthly means at each stations are calculated using the equation,

$$\overline{\delta_i} = \sum_{t=1}^{n} \delta_{ti} \tag{2}$$

where n is sample size $\geq$ 15, i is the ith station, t is the tth synoptic date (time is 00 GMT) and δ is 0/12 GMT difference from Equation 1. Finally, the root mean square (RMS) of the monthly means of all stations with a common instrument type in each select region are calculated for each mandatory pressure level up to 10 hPa according to the equation:

$$\delta_{rms} = \sqrt{(\sum_{i=1}^{m} \overline{\delta_i})} \tag{3}$$

where m is the number of stations with valid monthly means, i is the ith station and δ is the regional RMS. The instrument types are the Vaisala RS80-57H (WMO code 52) used in the Unitied States and the Vaisala RS80 Cora (WMO codes 60-63) used elsewhere. The selected regions are the entire globe, North America (bounded by 10N, 80N, 50W and 180W), Europe (30N, 80N, 60E and 20W) and Austrailia (45S, 0S, 160E, 90E).

3. Results

Data were processed for September 2001 by applying Equations 1, 2 and 3. Figures 1 and 2 show the vertical profiles for the RMS of the mean 0/12 GMT differences for select regions and months for the years 1999 to 2001. The 0/12 GMT differences from Vaisala RS80-57H rawinsondes are much larger than those from non-US rawinsondes over North America and elsewhere at levels as

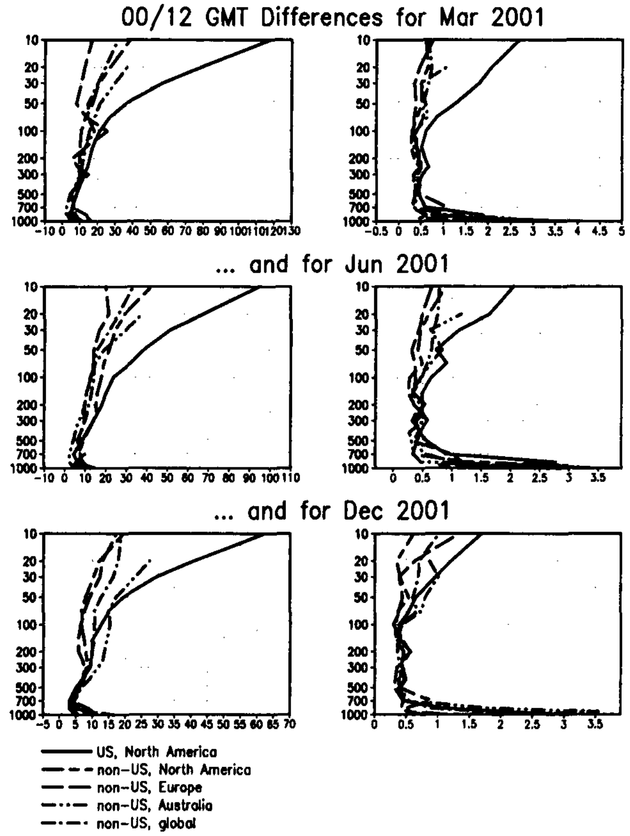


Figure 1. Regional root-mean-square of the mean 0/12 GMT differences at US and non-US stations calculated according to Eq. 3. Left and right panels correspond to height (m) and temperatures (°C), respectively.

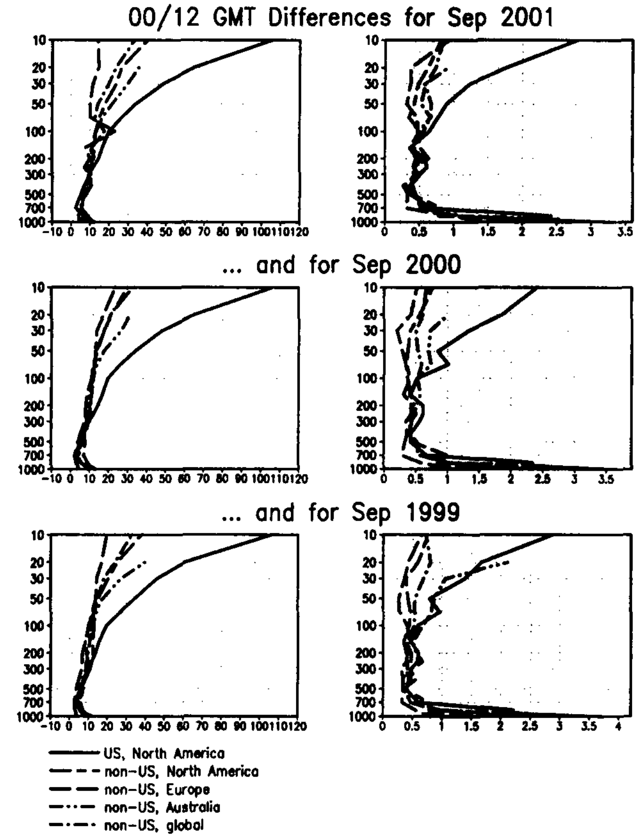


Figure 2. Same as Fig. 1 with different months and years

low as 100 hPa. The contrast in the RMS values from US and non-US rawinsondes for both temperature and heights increases with altitude so that at 10 hPa the values from US rawinsondes are twice that from non-US rawinsondes. In December, the 0/12 GMT differences are much smaller near the winter solstice when the northern hemisphere undergoes the longest nights during the year.

Figure 3 shows the horizontal distribution of the mean 0/12 GMT temperature differences over select regions at 30 hPa for September 2001. The largest means are over the Eastern US with lesser values elsewhere. There is also a sharp contrast between the values over the US and those over Canada where the magnitude of the means are much less. The large maxima over the central US is absent over Canada where no discenable pattern exists. A similar result can be obtained from a comparison between the means over the US and those over Europe and Australia. At other levels, similar patterns are evident over North America as shown in Figure 4 with values as large as 5°C at 10 hPa. The location of the maximum means shifts from east to west as altitude increases.

Figure 5 shows the variation of the patterns at 20 hPa for the months in 2001 listed in Figures 1 and 2. During March and September, the patterns, including the location of the maximum, are very similar. In June, the location of the maximum shifts to the eastern half of the US, and the magitudes of the mean differences decrease. The patterns in December are similar to that for June except that the differences are smaller during the month of maximum darkness. The same pattern persists in the years 1999 and 2000 as indicated in Figure 6.

For heights, Figure 7 reveals 0/12 GMT differences as high as 150 m at 10 hPa. Furthermore, the pattern is similar except that the location of the maximum is to the east. Again, no discenable pattern exists over

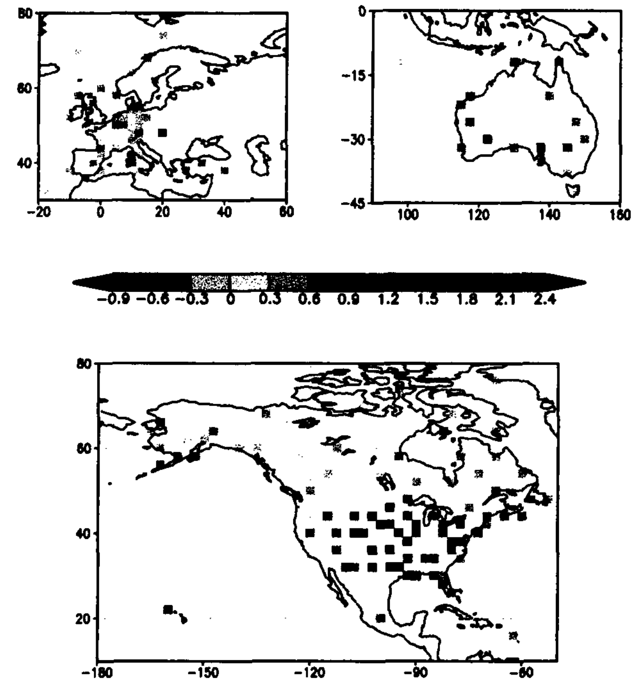


Figure 3. Mean 00/12 GMT temperature (°C) differences at US and non-US stations in select ragions at 30 hPa for September 2001. The mean differences were calculated according to Eq. 2

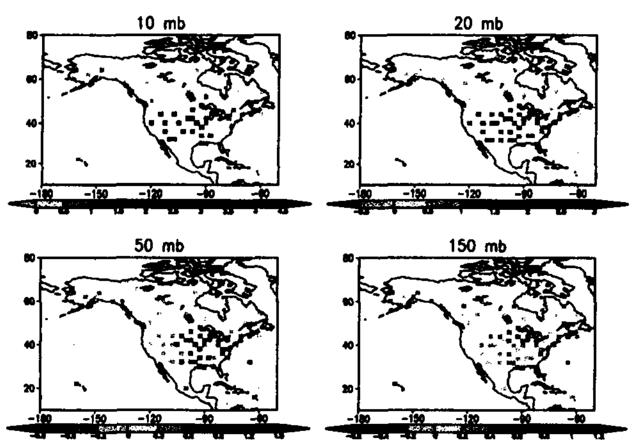


Figure 4. Same as Fig. 3 for select levels

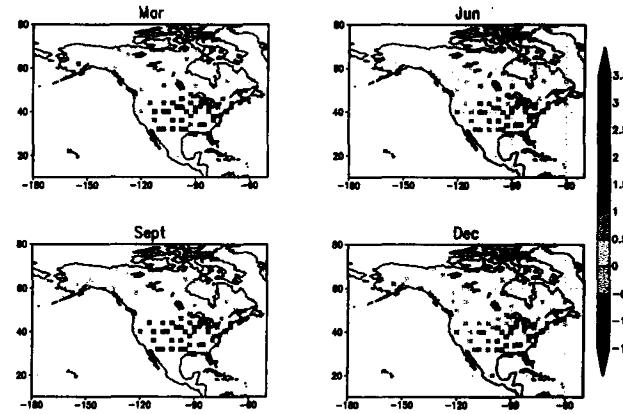


Figure 5. Same as Fig. 3 at 20 hPa for select months during the year 2001

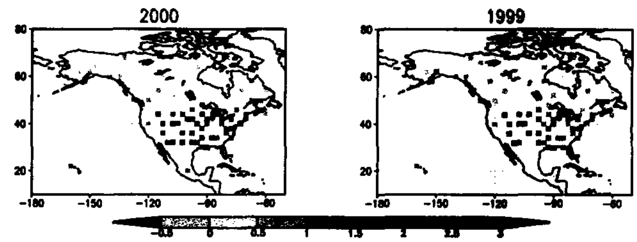


Figure 6. Same as Fig. 3 at 20 hPa for September, 1999 and 2000

Canada, where the average means are much smaller.

Time series plots of 0 GMT and 12 GMT temperature and heights at select stations have been examined. An example of the time-series plots is given in Figure 8 which presents the temperature and heights at 10 hPa for Semptember 2001 for select stations with longitudes of 101-103W. At US stations, the 0 GMT temperatures are consistently 2 to 4°C greater than those at 12 GMT so that the time-series plots for both synoptic times are roughly parallel to each other. At 30 hPa (figure not shown) the 0 GMT and 12 GMT temperature time-series are noisy but nonetheless the 0 GMT observations are predominately greater than the 12 GMT observations. The same is true for heights at both 10 hPa and 30 hPa except that the data is considerably less noisy.

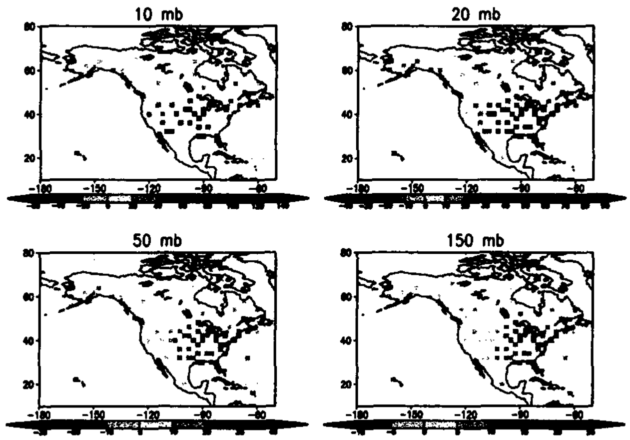


Figure 7. Same as Fig. 4 for heights (m)

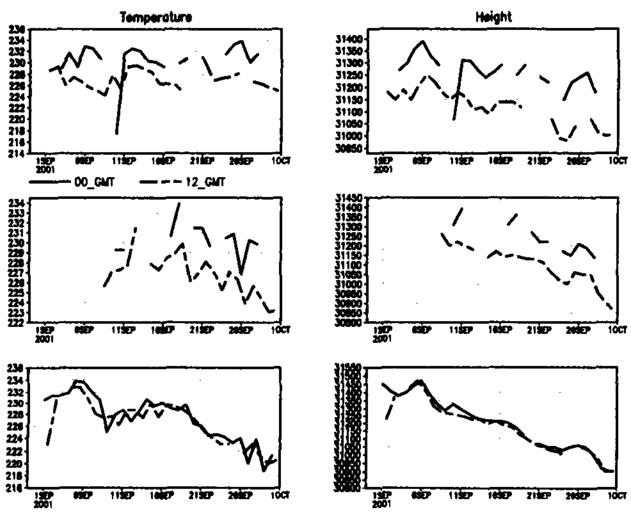


Figure 8. Time series of 10 hPa temperature (°K)and height (m) observations at 00 and 12 GMT during September 2001. The top, middle and bottom panals correspond to data from Amarillo, Texas, USA (WM0 # 72363), Rapid City, South Dakota, USA (WMO # 72662) and The Pass UA, Manatoba, Canada (WMO # 71867), respectively

At 10 hPa, 0 GMT heights are 100 to 150m higher than those at 12 GMT.

At the Canadian station, the time-series data at 10 hPa shows that the differences between the 0 GMT and 12 GMT data are much smaller than those at US stations. Other US and Canadian stations have been examined whose time-series plots are not shown. The plots for these stations are consistant with the horizontal plots shown earlier and that the plots for the 0 GMT and 12 GMT data are generally parallel especially at levels higher 50 hPa.

In summary, there are large systematic 0/12 GMT differences for both temperature and heights over the continental United States with monthly means as large as 5°C and 150 m. The location and magnitude of the maximum values vary with pressure (or altitdue) and time of the year. From the time-series plots the observed values at 0 GMT are consistently larger than those at 12 GMT. These differences are much larger than the values from stations using RS80 rawinsondes sondes outside of the Unitied States. In addition, the systematic patterns over the United States are absent elsewhere.

4. Analysis and Conclusions

As noted earlier, the observation data from the US rawinsondes obtained through NCDC and NCEP are nearly identical. Furthermore, the large systematic 0/12 GMT differences evident in the US observations are largely absent in observations from other stations that launch Vaisala RS80 rawinsondes. Thus, the source of the large 0/12 GMT differences is not from any subsequent NCEP post processing but must be unique to the on-site post-processing software at the US stations.

A possible source for the large systmatic 0/12 GMT differences involves the radiation bias correction scheme developed by Vaisala. Even though the correction scheme at US and most non-US stations are identical, the interface with the driver software is not. Vaisala's ground equipment and post-processing software is implemented at most stations worldwide, but at US stations the correction scheme is integrated into the NWS Micro-ART (Micro-computer Automated Radio Theodite) system. Thus, the 0/12 GMT large differences might largely be a result of the input data into the interface.

One such input that would be needed by the correction scheme is the launch time. If this input is in fact being mis-specified then the solar angle and the resulting bias correction would be mis-calculated. The rawinsondes in the continental US are typically launched near dusk or dawn, and as seen in Figure 9, the bias correction is very sensitive to the solar angle at these

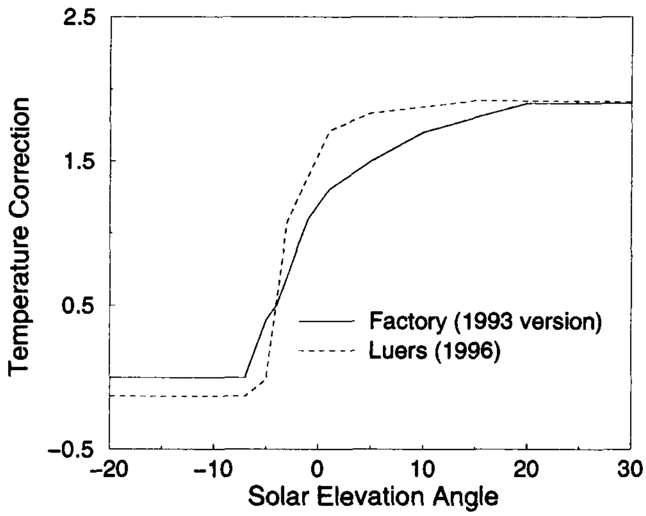


Figure 9. Temperature corrections (°C) versus solar elevation angle (°) at 15 hPa or about 30 km. Included for comparision are the corrections from the heat transfer model of Luers (1996), validated in Luers and Eskridge (1995)

synoptic hour (GMT)	launch time set to ...	
	actual	synoptic
0	2.32	-8.78
12	-6.47	4.60

Table 1. Solar elevation angles (°C) at a fictitious station at 40N and 105W on September 21, 2001. The pressure level and the ellapsed time since launch are assumed to be 10 hPa and 95 minutes. The actual bolloon launch time is assumed to be 58 minutes prior to the synoptic time.

synoptic hour (GMT)	launch time set to ...	
	actual	synoptic
0	1.83	0.0
12	0.11	1.96

Table 2. Temperature corrections (°C) at the fictitius station and with the parameters given in Table 1. The ventilation factor is assumed to be 1.1.

times of the day.

If the launch time were set to the synoptic hour, then the solar-angle would be miscalculated by about 10°. To illustrate the effect, a sample calculation was performed for a fictitious station near the location of the largest 0/12 GMT differences at 10 hPa (see Figures 4 and 7.) with input parameters typical at a US station (need reference?). The result of the sample calculation is given in Table 1. If the ballon is launched time is mis-specified to be the synoptic time, then the solar angle would be mis-calculated by about 11°. If -7° is the threshold for darkness, then for the synoptic hour 0 GMT, the post-processing system would assume darkness when in fact the thermistor is receiving sunlight. For the synoptic hour 12 GMT, the reverse is true.

The effect on the bias correction is seen in Table 2 where at 0 GMT launch the bias correction should have been nearly 2°C but would have been set to 0°C if the launch time was mis-specified to be the synoptic hour. For the synoptic hour 12 GMT, the opposite is true. Thus, the sensor would measure a temperature too high and low by nearly 2°C for 0 and 12 GMT, respectively. The mis-calculation at these two synoptic times would account for 3.5 to 4.0 °C of the 4.5 to 5.0 °C 0/12 differences that is typically observed for the mean 0/12 GMT differences in the central US. Much of the remaining differences can be attributed to the factors that cause the 0/12 GMT differences at non-US stations which have values of about 0.5 to 1.0 °C (see Figures 1 and 2).

This hypothesis was tested by first uncorrecting the observations with the assumption that the launch time was set to the synoptic hour. In the calculations, Vaisala's correction table (1993 version) and its formulae for solar elevation and ventilation factor were used (Vaisala, 1983). In addition, upper air data from NCDC was used to aquire the elapsed time and merge it with the data from NCEP. After uncorrecting the data, recorrections were then performed using the actual launch time.

Figure 10 show the vertical profiles for the RMS of the mean 0/12 GMT differences of the unmodified and recorrected observations from US rawinsondes and observations from the Canadian sondes. The 0/12 GMT differences of the recorrected observations become much smaller and much closer to the RMS of the means over Canada. For heights, vertical profiles are nearly identical for the observations over the US and the unmodified observations over Canada. For temperatures, the vertical profiles begin to diverge above 30 hPa but the RMS for corrected US observations remains closer to the RMS for the observation over Canada than those for the unmodified US observations.

Figure 11 compares the patterns of the means at

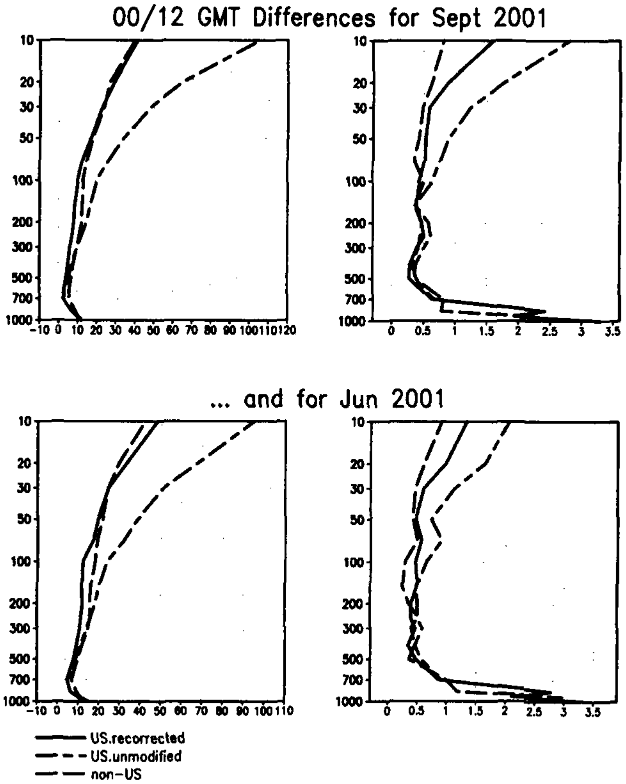


Figure 10. Same as Fig. 1 with recorrected data from US stations

30 mb for the recorrected and unmodified temperature observations. The figure shows that the patterns of the means over Canada and the United States have become indistinguishable. For heights, the patterns remain different over Canada and the US where the means over the western States have become negative but smaller in magnitude. The large values over the the eastern half of the US are much smaller, and the means over the area near the maximum 0/12 GMT differences has been reduced to near zero. A similar pattern exists for recorrected temperatures and heights at 50 hPa (figure not shown). At 10hPa in Figure 12, the patterns for the recorrected heights become consistent with those over Canada. For temperature the patterns persist, and significant differences remain but are reduced by about one-half.

Time series plots of 0 GMT and 12 GMT for the recorrected temperature and heights have been compared with those for uncorrected observations, examples of which are given in Figures 13 and 14. At many stations like Amarillo, Texas, the time series show that the lines connecting the recorrected 0 and 12 GMT observations become much closer. At other stations like Greensboro, North Carolina, only a modest change in the time series is evident.

Figure 11. Mean 00/12 GMT differences, both recorrected and unmodified, at 30 hPa for September 2001. The top and bottom panals corresponds to temperature (°C) and heights (m). The mean differences were calculated according to Eq. 2

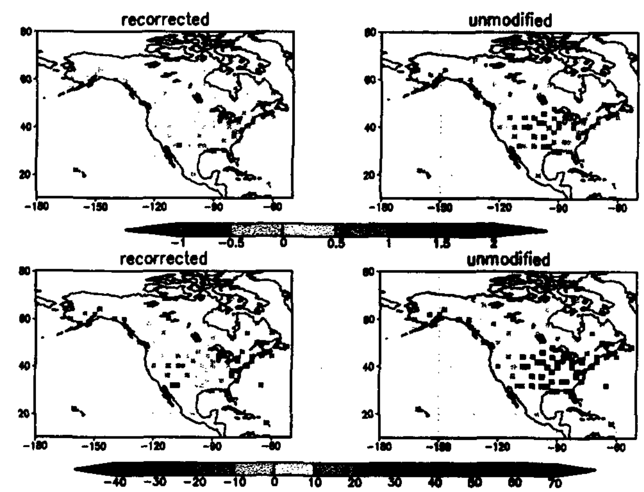
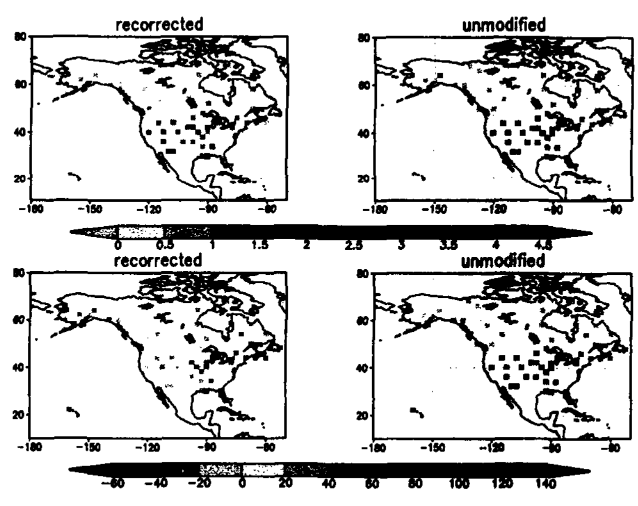


Figure 12. Same as Fig. 11 except at 10 hPa



In summary, the large 0/12 differences over the con-

Figure 13. Time series of temperature (°K) observations, recorrected and unmodified, at 00 and 12 GMT during September 2001. The top, middle and bottom panals correspond to data from Amarillo, Texas at 10 hPa, same location at 30 hPa and Greensboro, North Carolina (WMO #72317) at 30 hPa, respectively.

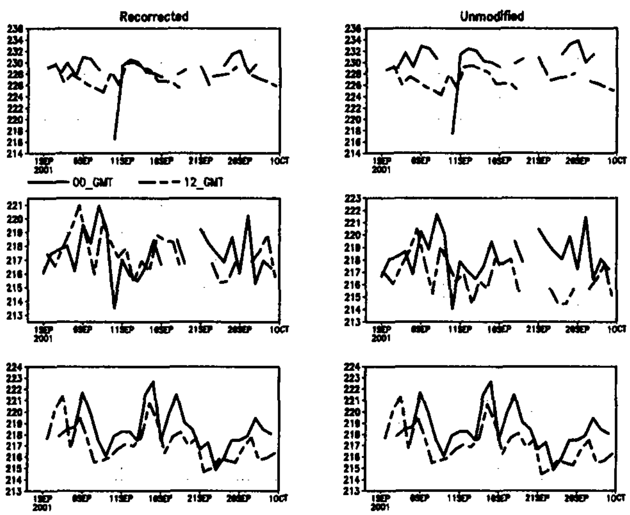
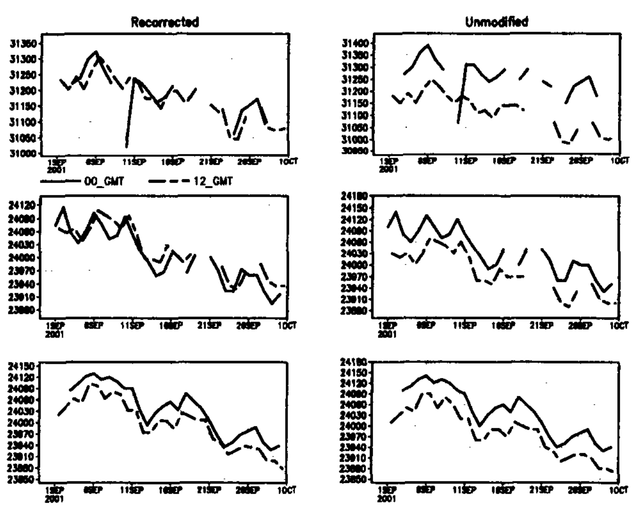


Figure 14. Same as Fig. 14 for height (m) observations



tinental US are greatly reduced if the observations are uncorrected assuming that the launch time is set to the synoptic time and recorrected using the actual launch time. However, some of the differences persist and there remains a contrast between the patterns over the US and Canada. Thus, if the launch time were set to the synoptic, then other factors would exist which would also contribute to the 0/12 GMT differences. In any case, the data clearly shows that 0/12 GMT differences are largely artificial especially over the central US and that the differences largely originate in the post processing software at the observing stations.

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